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PTEROSTICHUS BEETLES DOMINATE THE CARABID ASSEMBLAGE IN AN UNSPRAYED ORCHARD IN SONOMA COUNTY, CALIFORNIA

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Abstract.—The seasonal activity of predatory carabids on the soil surface was examined in an unsprayed apple orchard in Sonoma County. *Pterostichus* beetles were the most active carabids in this orchard, comprising from 71–83% of the total number of individuals trapped during two consecutive growing seasons. *Pterostichus* (*Dysidius*) *lustrans* LeConte and *Pterostichus* (*Hypherpes*) spp. were most active in June 1991 and June 1992, whereas *Pterostichus* (*Poecilus*) *cursitor* LeConte were most active in July and August 1991 and in July 1992.

Key Words.—Coleoptera, Carabidae, *Pterostichus,* seasonal activity, orchards

Adults of the carabid genus *Pterostichus* are important predators of insect pests in agroecosystems (Hagley & Allen 1988, Allen & Hagley 1990, Cárcamo & Spence 1994, Clark et al. 1994, Riddick & Mills 1994, Wallin & Ekbom 1994). In apple orchards, especially those containing semidwarf trees, *Pterostichus* beetles help suppress codling moth (*Cydia pomonella* (L.)) populations by attacking fifth-instar larvae wandering on the soil surface prior to pupation (Riddick & Mills 1994). Determining the seasonal activity of these carabids in relation to when *C. pomonella* larvae are wandering on the ground is important. If the surface activity of *Pterostichus* species coincide with the time that codling moth larvae are seeking pupation sites, these carabids can contribute significantly to the suppression of this pest. First generation *C. pomonella* larvae leave fruit during May or June in orchards in California (Pickel et al. 1986), and thereafter become vulnerable to predation by *Pterostichus* adults on the ground.

Pesticide sprays have been shown to alter the surface activity of adult carabids in apple orchards. For example, *Harpalus pensylvanicus* DeGeer were significantly more active in plots sprayed with granulosis virus in early July, than in plots sprayed with *Bacillus thuringiensis* Berliner (Dipel) plus oil, or controls (no-spray); *Chlaenius tricolor* Dejean were significantly more active in plots sprayed with oil alone, in early June, than in plots sprayed with granulosis virus, *B. thuringiensis* plus oil, or controls (Riddick & Mills 1995). In unsprayed apple orchards, an accurate assessment of the seasonal pattern of activity for *Pterostichus* species can be made.

MATERIALS AND METHODS

The study site was an unsprayed apple orchard located in the coastal region of northern California (Sonoma County), near Sebastopol, a major apple-growing district. The orchard contained trees of Golden Delicious and Rome Beauty apple varieties. This ≈2 ha orchard was bordered by a woodlot, meadow, and residence

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on three sides. The fourth side bordered a paved roadway that separated it from an ≈20 ha sprayed, commercial orchard. The number of trees in this orchard was not determined, but an estimate is that it contained ≈20 tree rows, each with an average of 20 trees. The soil was disked (as a means of retaining soil moisture) in late April to early May, and the natural grasses and herbs that were uprooted were left on the soil surface. Pesticides were not sprayed in this orchard between April 1991 and September 1992.

The carabid assemblage was sampled during two consecutive seasons using pitfall traps, the standard technique for sampling carabids (Greenslade 1964, Rivard 1965, Luff 1975, Morrill 1975, Adis 1979, Baars 1979a, Halsall & Wratten 1988). Trap catch estimates the activity of adult carabids on the soil surface and whole season trapping reflects the density of carabid populations (Ericson 1979, Hokkanen & Holopainen 1986). Traps were plastic cups (473 ml), with a 9 cm diameter opening, sunk into the ground with the rim flush with the soil surface. Leaf litter within 20 cm of the perimeter of each trap was removed and the soil smoothed to facilitate the movement of carabids around the traps (Greenslade 1964, Powell et al. 1985). (However, this procedure could have introduced sampling bias against species that avoid crawling onto smoothed soil.) Traps were filled to the one-quarter mark with a solution of water and liquid detergent, so that captured beetles sank to the bottom of the trap. A preservative was not used because it might alter the catch and sex ratio of the trapped species (Holopainen 1992).

Six pitfall traps were positioned, one tree apart, in a single row of trees at the center of the orchard in 1991. Traps were in place for 6–10 consecutive days during each of four sampling periods in 1991, 4–11 June, 3–9 July, 30 July–9 August, and 4–11 September. In 1992, sampling effort was increased, such that five traps were positioned, one tree apart, in each of three rows of trees. The three sample rows were equidistant within the orchard; five tree rows apart. Traps were in place for three consecutive days during each of six sampling periods, 20–23 April, 11–14 May, 5–8 June, 7–10 July, 28–31 July, and 18–21 August. Samples were collected on the last day of each sampling period. Trapped carabids were sorted to species or species groups in the laboratory.

Voucher specimens are deposited at the Laboratory of Biological Control, University of California, Berkeley, and the Department of Entomology, University of Maryland, College Park.

Results

Adults of *Pterostichus* species were the most active carabids in the unsprayed orchard, representing 71–83% of the total number of individuals trapped over the two seasons. Adult *Trechus, Amara,* and *Anisodactylus* species were less active. In 1991, a total of 511 carabids were captured on four collection dates (Table 1). The species that represented 3% or more of the carabids include *Pterostichus* (*Dysidius*) *lustrans* LeConte, *Pterostichus* (*Hypherpes*) spp., *Pterostichus* (*Poecilus*) *cursitor* LeConte, *Trechus obtusus* Erichson, *Amara* spp., and *Anisodactylus californicus* Dejean. *Pterostichus* (*Hypherpes*) spp. represents two species, *Pterostichus californicus* (Dejean) and *Pterostichus castanipes* (Ménétriés) which are morphologically similar, and not readily distinguishable at the time that this research was undertaken. Subsequent identifications of pinned specimens (collected

Table 1. Percentage and number of carabid beetles active during two consecutive growing seasons.

Carabid species	1991 collection		1992 collection	
	%	[No.]	%	[No.]
Pterostichus lustrans LeConte	35.62	[182]	44.04	[340]
Pterostichus cursitor LeConte	13.31	[68]	26.29	[203]
Pterostichus californicus (Dejean) & *Pterostichus castanipes* Ménétriés	22.11	[113]	12.30	[95]
Trechus obtusus Erichson	10.76	[55]	3.11	[24]
Amara spp. (2+ species)	8.02	[41]	5.83	[45]
Anisodactylus californicus Dejean	4.89	[25]	4.40	[34]
Anisodactylus similis LeConte	2.93	[15]	0.39	[3]
Bradycellus spp. (2 species)	0.78	[4]	1.68	[13]
Calathus ruficollis Dejean	0.39	[2]	0.39	[3]
Dicheirus piceus Menetries	0.19	[1]	0.52	[4]
Loricera foveata LeConte	0.19	[1]	0.91	[7]
Microlestes sp.	0.19	[1]	—	—
Agonum fossigerum Dejean	0.19	[1]	—	—
Tanystoma maculicolle (Dejean)	0.19	[1]	—	—
Scaphinotus sp.	—	—	0.13	[1]

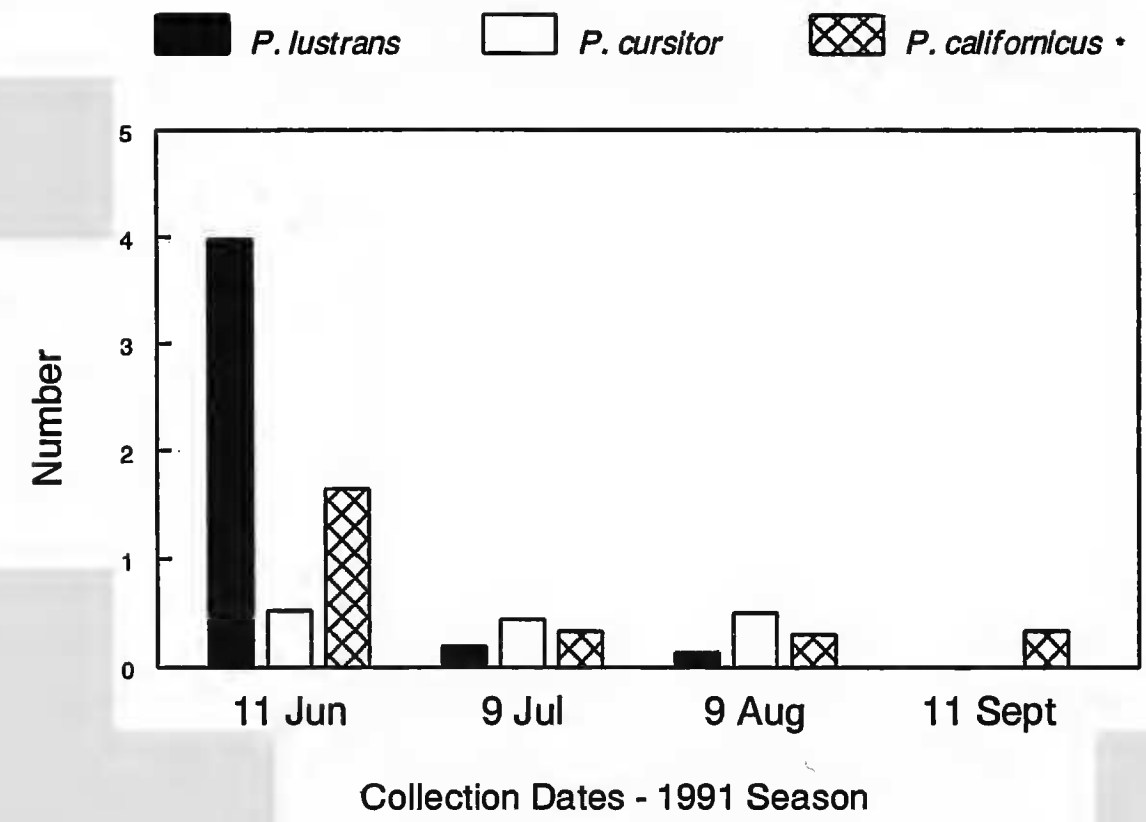
during the 1991 and 1992 seasons) indicated that *P. californicus* comprised ≈91% and *P. castanipes* comprised ≈9% of the *P.* (*Hypherpes*) spp. group in this orchard. At least two species of *Amara* were included in the catch; however, I was unable to identify them to species.

In the 1992 season, 772 carabids were collected on six collection dates (Table 1). The species that represented 3% or more of the carabids include: *P. lustrans, P. cursitor, P.* (*Hypherpes*) spp., *Amara* spp., *A. californicus,* and *T. obtusus.*

The seasonal activity of *Pterostichus* beetles was determined in both seasons. In 1991, *P. lustrans* adults were the most active carabids in early June and their activity sharply declined through July and August (Fig. 1). *Pterostichus cursitor* were less active, but their activity remained constant from early June to August. Although *P.* (*Hypherpes*) spp. were most active in early June, their activity continued into early September. In 1992, adults of *P. lustrans* were again the most active carabids early in the season from late April through June. Adults of *P. cursitor* appeared more active in late April and early July, and their activity was more variable than in 1991. Adults of *P.* (*Hypherpes*) spp. were again most active in early June. All *Pterostichus* beetles were active on each collection date in the 1992 season.

Discussion

Pterostichus species comprised from 71–83% of the carabid assemblage in the unsprayed orchard. In a nearby sprayed, commercial orchard (which was located 91 m from the unsprayed one), *Pterostichus* species represented 45% of the total carabids trapped in the 1991 season, but only 19% of the total in 1992 (Riddick & Mills 1996). The greater percentage of trap captures of *Pterostichus* species in the unsprayed orchard may, in part, result from a lack of insecticide applications against codling moth and the presence of suitable alternative prey for these decidedly carnivorous carabids to feed on.



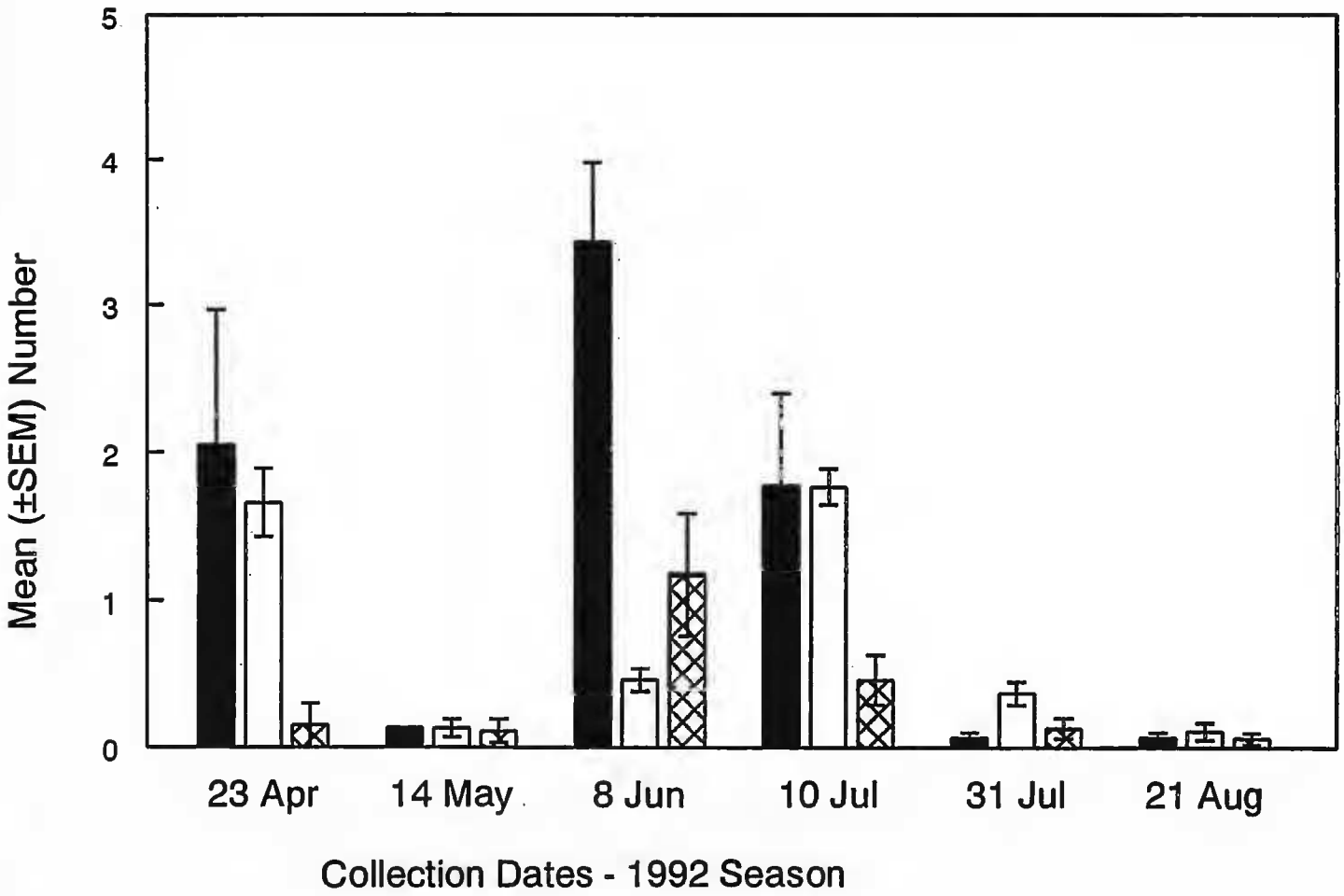


Figure 1. Number of *Pterostichus* adults per trap per day in a single tree row in the 1991 season, and the mean (±SEM) number of *Pterostichus* adults per tree row per trap per day in the 1992 season. Three tree rows were sampled in 1992. *, represents two morphologically similar species, *P. californicus* (≈91% of the *Hypherpes* group in sample) and *P. castanipes* (≈9%).

The most active carabids in the sprayed orchard were *Amara* species; they comprised 31% of the carabids in 1991 and 63% in 1992. *Amara* species were significantly less active on at least one collection date, in both seasons, in plots managed with conventional insecticides (Riddick 1993). The *Amara* species became dominant in a sprayed orchard despite some individuals being affected by the insecticides.

The presence of woodlot and meadow adjacent to the unsprayed orchard may have contributed to the greater activity of *Pterostichus* beetles, as well. It is unclear why other species, such as *Amara* spp. did not experience increased activity, but *Amara* are infrequently captured in woodlands, possibly due to the lack of grass seeds, a preferred food source for adults (see Niemelä et al. 1992). Exchange of carabids and spiders between cultivated fields (or orchards) and semi-natural habitats has been documented (Altieri & Schmidt 1986, Coombes & Sotherton 1986, Duelli 1990, Dennis & Fry 1992, Kajak & Lukasiewicz 1994). *Pterostichus* beetles overwintering in the adjacent woodlot or meadow, might have dispersed into the unsprayed orchard in the spring (perhaps in early April). In contrast, movement from the woodlot or meadow into the sprayed, commercial orchard would have been limited, because both natural areas were located on the opposite side of the roadway. Roadways can become a barrier to adult carabids that disperse primarily by crawling (Mader 1984, Mader et al. 1990).

Adult *Pterostichus* species were never seen flying at the margins of either orchard. Both *P. californicus* and *P. castanipes* are flightless. *Pterostichus lustrans* and *P. cursitor* are fully-winged (macropterous) and probably disperse by flight, to some extent, from overwintering sites.

The seasonal activity of the four *Pterostichus* species was similar in the unsprayed orchard. *Pterostichus lustrans* adults were the most active, especially in June or July. But the reduced activity of *P. lustrans* in August in both orchards may have resulted from inadequate moisture and high temperatures at the soil surface. The climate in the Sebastopol region is Mediterranean, characterized by hot, dry summers and mild, wet winters (Altieri & Schmidt 1986). The lack of ideal conditions for activity may have influenced the adults to remain beneath the soils surface, late in the season.

The high June activity of *P. lustrans* adults suggests that they have the greatest potential for searching for and consuming fifth-instar larvae of the codling moth on the soil surface. First generation *C. pomonella* larvae drop from fruit and search for pupation sites in early June (Pickel et al. 1986). The ability of these carabids to locate the wandering larvae may depend on the hunger level of the individuals. Hungry carabids may forage for prey more effectively than satiated individuals (Baars 1979b, Mols 1987, Wallin & Ekbom 1994). The seasonal activity and feeding behavior of *P. lustrans* larvae is unknown, but it is conceivable that these predatory larvae could attack and kill *C. pomonella* larvae that enter the soil to pupate.

The conservation of *Pterostichus* populations in apple orchards is necessary if these natural enemies are to become components of an integrated pest management program. This current research suggests that the conservation of the more predatory carabids in California orchards may involve a reduction in pesticide usage. Maintaining natural areas (meadow, woodlot or hedgerows) in the immediate vicinity of orchards, or non-crop plants within orchards, might help conserve

and enhance *Pterostichus* species populations during the season (see Altieri & Schmidt 1985, Altieri 1991, Thomas et al. 1991, Lys & Nentwig 1992).

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